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Charles D. and Mary Vaux Walcott
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FORAMINIFERA FROM THE HADLEY HARBOR COMPLEX, MASSACHUSETTS

KW: General
Paleontology

BY

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INTRODUCTION

THIS STUDY is a survey of the Foraminifera from the Hadley Harbor Complex. Its purpose is to outline the distribution of the species, measure their diversity, and examine the relationship of these faunal characteristics to the environmental subareas of the Complex.

The Hadley Harbor Complex lies about 6 miles southwest of Woods Hole, Massachusetts. The general configuration of the area is shown in figure 1. Parker et al (1964) have outlined four environments or subareas within the Hadley Harbor Complex. They are: (a) channels; (b) Vineyard Sound channels; (c) inner harbor; (d) outer harbor. For the purpose of this study the channel a and b subareas will be combined. These channel subareas are shown as "gutters" in figure 1. High velocity currents sweep diurnally through these channels and the Vineyard Sound gutters are also subjected to strong wave action. Sediments in the gutters are variable, but usually are coarse sands. The second subarea of this study, called the inner harbor, includes the area so labeled on the map as well as the deeper area of Hadley Harbor itself. This inner harbor subarea has quiet waters and deposition of silts and clays. Finally, there is the outer harbor subarea, which is subjected to moderate circulation and wave action and has a sandy silt bottom. This subarea includes the area just south of the Vineyard Sound gutters as well as the shallower areas of Hadley Harbor itself. Much of the area except for the high-energy gutters and sand flats of the outer harbor contain seasonal eel grass.

Parker et al (1964) measured several environmental variables and showed that the pH and salinity were nearly constant in all subareas (7.8–8.1 and 31–32 ‰). Eh varied considerably spatially and temporally, especially in the inner harbor subarea where reducing conditions often were present. Light penetration was also minimal in the turbid inner harbor waters. The outer harbor subarea showed the least fluctuation in environmental variables.

ACKNOWLEDGMENTS

This study was made in cooperation with the Systematics-Ecology Program of the Marine Biological Laboratory (MBL), Woods Hole, Massachusetts. I am grateful to Dr. Carriker and Dr. Parker of the MBL for all the assistance they have given me. Thanks also to D. Boucher, T. Levinson, L. Overby, and M. C. Taylor for their laboratory assistance, and Drs. Ellison, Gibson, and Smith who reviewed the manuscript and offered helpful suggestions. The study was supported in part by the Ford Foundation.

METHODS

Samples were collected by means of a small coring tube $1\frac{5}{8}''$ in diameter or by a small (0.1 sq m) Van Veen sampler. In each case, about 10 ml of surficial sediment was removed and placed in a 10 percent solution of buffered formalin.

About 0.1 g of Rose Bengal stain (see Walton, 1952) was added to each sample a day prior to examination. After staining, the samples were washed over a 63μ sieve, dried, and floated, using bromoform with a specific gravity of 2.4. All material which did not float was examined for Foraminifera to insure complete recovery. In most cases very few specimens were found in the sink. For a discussion of the method, see Gibson and Walker (1967).

After the preparation outlined above, the samples were re-wet with water to which a few drops of ethylene glycol, a wetting agent, was added to surpress floatation of the specimens. The samples were then picked and/or counted to determine the number of individuals in the various species.

DISTRIBUTION

The initial collecting date was in July 1964. These 1964 stations are numbered 95 through 119. The area was sampled a second time

during April 1965. These stations are numbered 259 through 272. The location of the stations occupied at the two sampling times is shown in figures 1 and 2. The number of individuals for each species in the living and total populations is shown in table 1. The suffix g indicates a grab sample, c a core sample. A prime indicates a replicate.

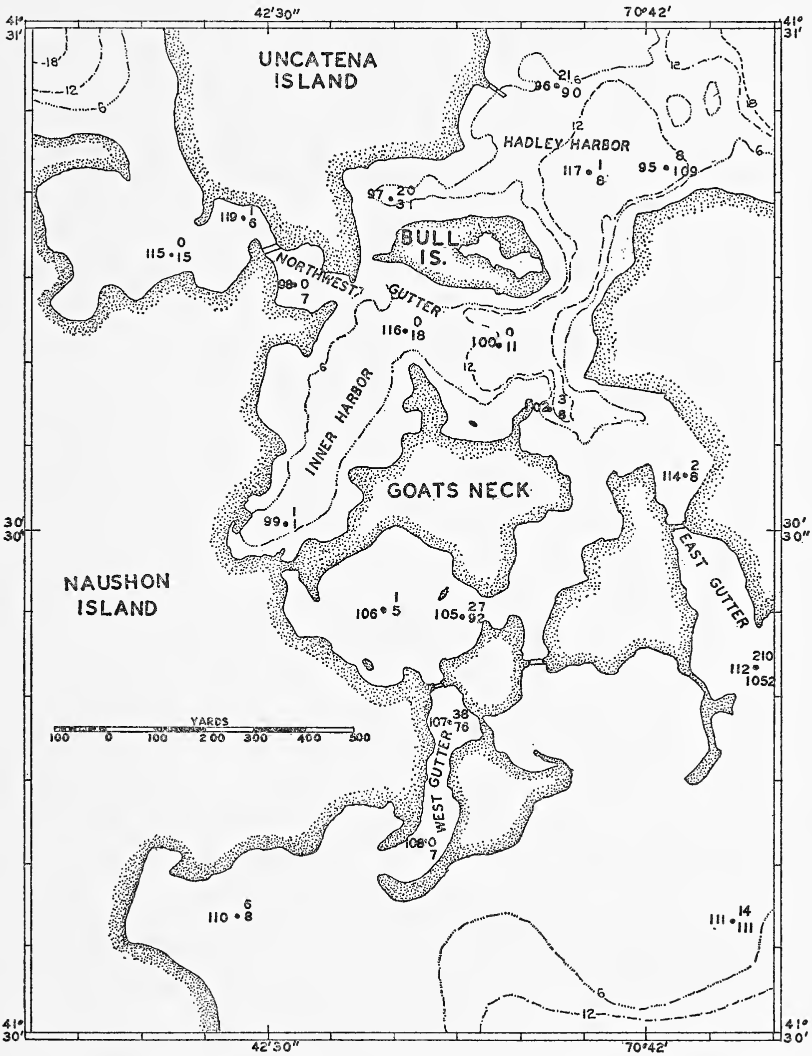

FIG. 1.—Number of individuals in the living (top number) and total (bottom number) populations in July 1964.

SAMPLE PAIRS

Seven pairs of samples were taken in April 1965. Each pair was taken from a single grab sample 0.1 sq m in area. To examine homogeneity of species proportions at a station (not between stations), the data were arranged in contingency tables. The "goodness of fit" between the observed and expected numbers was then analyzed by means of chi-square. Species for which the expected frequency is less than two were deleted from the calculation of chi-square. For some pairs (sta. 262, 265, 266) the expected frequency for all species is less than two and no analysis was attempted. These contingency tables are shown in table 2.

Of the pairs which could be tested, none of two for the living population and two of four for the total population have species proportions which agree with expectation. Although the pair 262-262′ could not be tested, it is clearly heterogeneous. The pair 266-266′ and the living population of the pair 270-270′ may also be heterogeneous. In the Complex as a whole we may be confident that species proportions are homogeneous in sample pairs at about one third of the stations. In this respect the Hadley Harbor Complex is similar to the nearshore area of Long Island Sound. Buzas (1965) found two of five sample pairs homogeneous for the living population and one of six for the total population in the nearshore (<20 m) areas of Long Island Sound. The offshore areas of Long Island Sound are, however, more homogeneous than the nearshore areas. In the Hadley Harbor Complex, sampling is not adequate to permit drawing any conclusion between subareas.

The reason why sample pairs often fail a test for homogeneity is because individual foraminifers are not all randomly distributed. Buzas (1968) has shown that species with relatively low densities have randomly distributed individuals, but as the density increases they become progressively more aggregated. This is an unfortunate situation because those species which are most abundant and consequently most likely to be included in any test of homogeneity are the ones which are most aggregated in their distribution.

FAUNAL COMPOSITION

Sixteen species were recorded from the samples taken in July 1964 (see table 1). The most abundant species was *Elphidium clavatum. E. incertum, Buccella frigida,* and *Ammonia beccarii* were also relatively abundant. A relatively large number of individuals belonging to *Quinqueloculina seminula* were found at stations 96 and 107.

Nineteen species of Foraminifera were recorded from the samples collected during April 1965 (see table 1). The total number of species recorded from both sampling times is 22. In April 1965 the species *Elphidium clavatum* was again the most abundant. *E. subarcticum, A. beccarii,* and *B. frigida* were also relatively abundant. A few

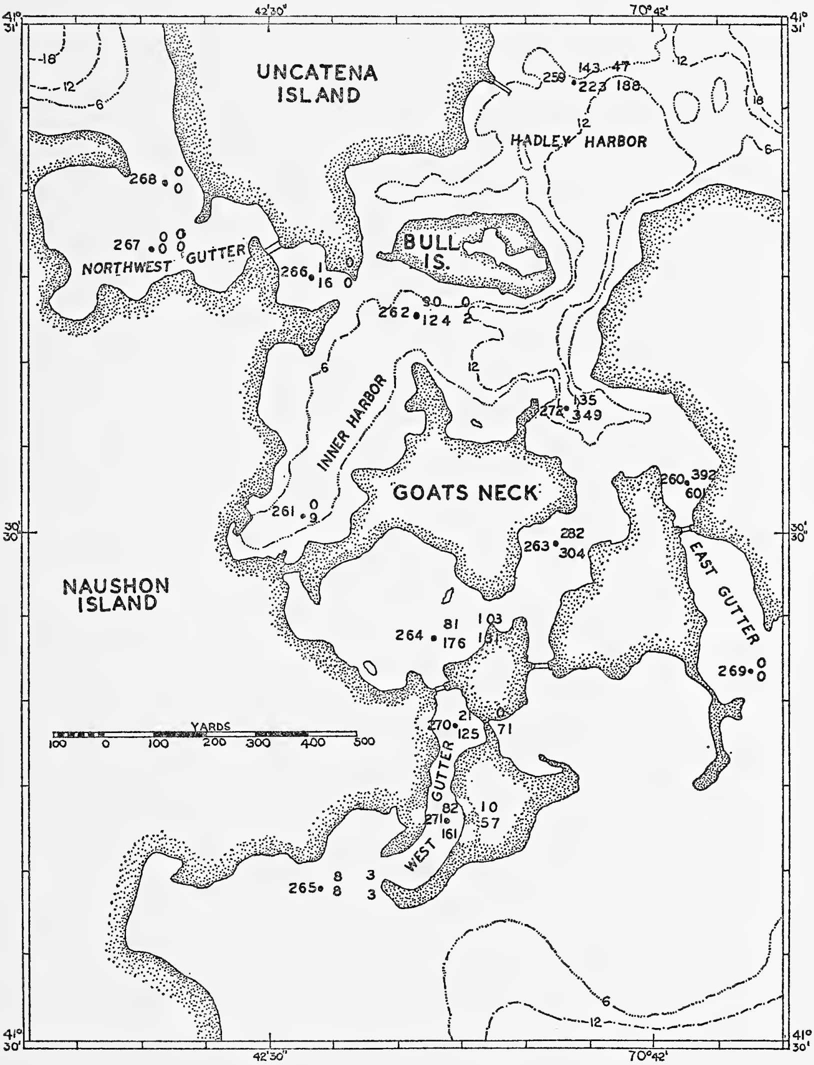

FIG. 2.—Number of individuals in the living (top number) and total (bottom number) populations in April 1965 (paired numbers=replicates).

individuals belonging to *Quinqueloculina seminula* were found at station 259 which is approximately at the same location as the 1964 station 96.

SPATIAL HETEROGENEITY

The total number of individuals (all species) found at each station for the living and total populations for the sampling times July 1964 and April 1965 is shown in figures 1 and 2, respectively. Plots of the distributions of the more abundant species were also prepared but are not shown here. The only clearly discernible pattern (for both sampling times) is that some areas have Foraminifera and some have very few or none. The gutters and outer harbor subareas have the largest foraminiferal populations. The inner harbor and northwest gutter subareas are conspicuously barren.

Stations less than 200 yards apart which might be expected to be subjected to the same environmental variables and belong to the same general subarea, such as gutters or outer harbor, show marked variation. For example, as is shown in table 1, stations 105-106, 107-108, and 95-117 for July 1964 and 266-266′, 265-272, and 264-270 for April 1965 differ widely. Clearly, there is spatial heterogeneity in a very small area. Likewise, stations which are at approximately the same locality, but were sampled at different times show a great amount of heterogeneity. Stations 102-272, 114-260, and 96-259 are approximately at the same locality but differ markedly in their contents. More foraminifers were recorded in April 1965 than in July 1964. Because of the great spatial heterogeneity, however, it is impossible to say how much of the variation is due to change with time. Unfortunately, no cores were analyzed to show how this variation would appear in a single column of sediment representing a substantial (a few thousand years) amount of time.

The great amount of spatial heterogeneity found in the Hadley Harbor Complex contrasts markedly with areas such as the offshore area of Long Island Sound. There Buzas (1965) found that in the living population two samples consisting of five stations each picked at random from 10 stations which were located a mile apart along a traverse did not differ significantly. This kind of difference is to be expected. The offshore area of Long Island Sound is homogeneous with respect to sediment type as well as other environmental variables (see Riley, 1956). Other shallow areas, however, as shown by Buzas (1965) for Long Island Sound, by Ellison (1966) for the Rappahannock Estuary, and by Lynts (1966) for Florida Bay are spatially heterogeneous.

DIVERSITY

Species diversity in the Hadley Harbor Complex was investigated by means of the Shannon-Weiner information function. The function is defined as $H(S)=\sum_{i=1}^{S} p_i \ln p_i$ where S is the number of species

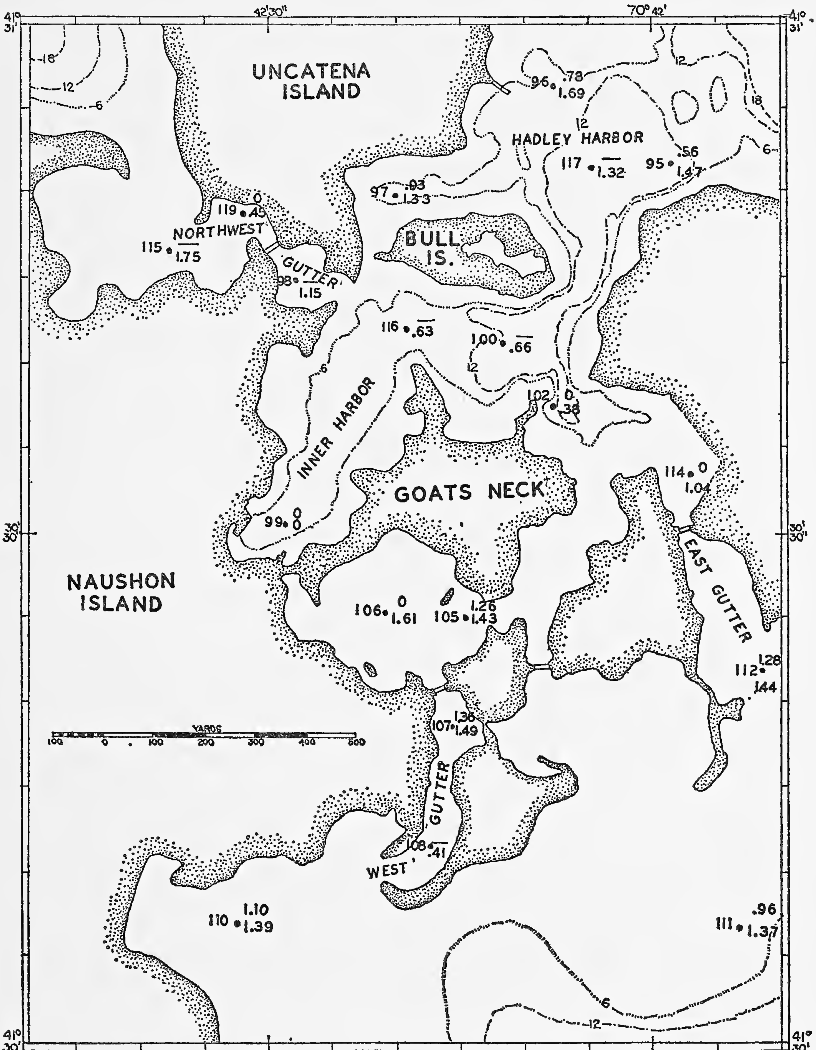

FIG. 3.—H(S) values for the living (top number) and total (bottom number) populations in July 1964 (O=only 1 species present; – =no foraminifers).

and p_i is the proportion of the ith species. The function was used as a measure of species diversity by MacArthur and MacArthur (1961). A readable account of its derivation and properties is given by Quastler (1956). The function takes into account not only the number of

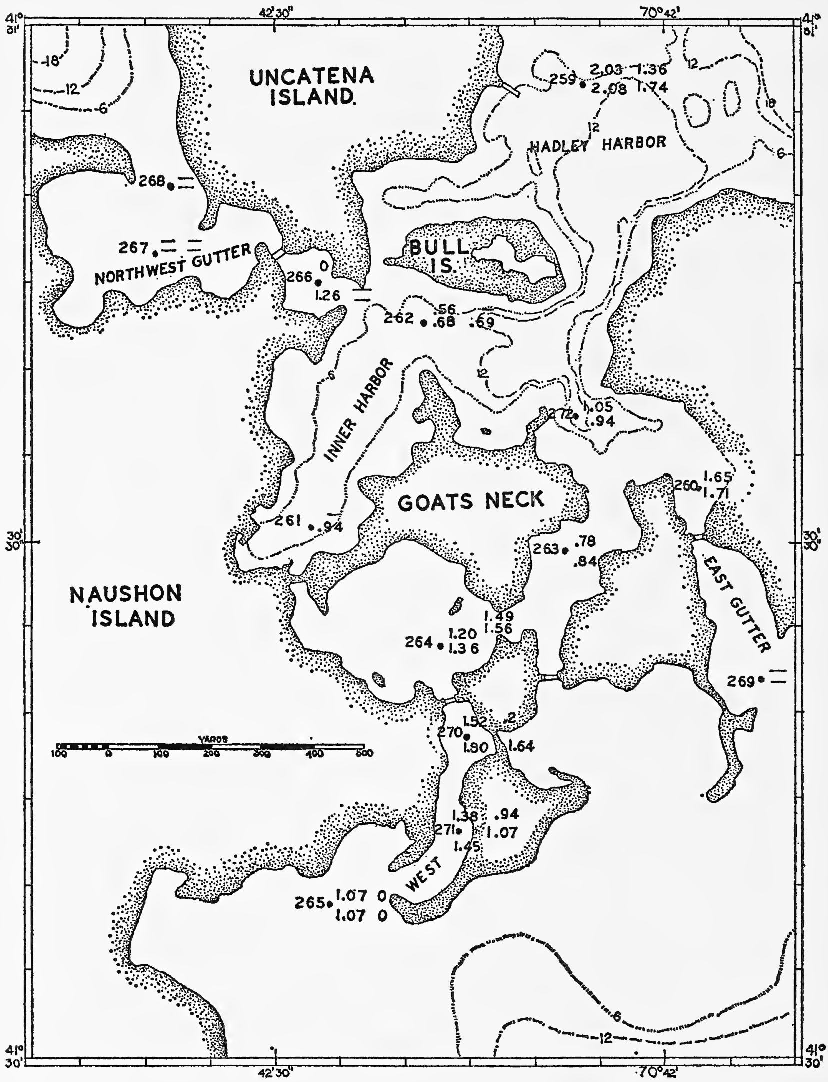

FIG. 4.—H(S) values for the living (top number) and total (bottom number) populations in April 1965 (O=only 1 species present; - =no foraminifers; paired numbers=replicates).

species, but also their relative abundance, and summarizes this information as a single number. It behaves, as the field observer intuitively would, by giving more "weight" to those species which are most abundant and much less to species which are rare.

The function was calculated for the living and total populations at the two sampling times. The results are shown in figures 3 and 4. The top number at each station is for the living population and the bottom for the total. At those stations at which replicates were taken the two sets are shown.

The values of the information function for the paired samples which are shown in figure 4 indicate that the function can be estimated fairly well from a single sample. The variation usually is less than .7, except for stations 265, 266, and 270, where the number of Foraminifera is very low.

The April 1964 sampling time has, in general, higher diversity values than the July 1964 sampling time. The number of individuals was considerably greater in April 1965 (see table 1). Because the information function is calculated only from proportions it can be independent of density. However, the number of species observed is often a function of the number of individuals examined (see Preston, 1962) and so in samples with very many individuals the addition of the 'rare' species increases the value of the function. Although higher diversities were recorded in April 1965, the pattern of distribution of the indices is similar for both sampling times. The highest diversity occurs in the outer harbor (stations 96 and 259). Diversities are also relatively high in the gutters. The area of lowest diversity is in the inner harbor, especially northwest of Goats Neck, where values of 0 (1 species) or no values (no Foraminifera) occur.

The values of H(S) in the Hadley Harbor Complex are similar to those calculated for Long Island Sound, Buzzards Bay, and Cape Cod where values of less than 2 are the rule. Values of H(S) calculated from Parker's (1948) open-ocean data in the surrounding area are usually over 2.

RELATIONSHIP OF FAUNA TO ENVIRONMENTAL SUBAREAS

No apparent simple relationship between the distribution of foraminiferal species and the environmental subareas outlined previously was found. That is, no simple assemblage characteristic of outer harbor, inner harbor, and gutter subareas can be defined. The only clearly discernible pattern is that most of the gutters and outer harbor

subareas have Foraminifera whereas the inner harbor and northwest gutter do not. The reducing conditions measured by Parker et al (1964) might contribute to the absence of Foraminifera in the inner harbor subarea, but studies from other areas with reducing conditions, for example Buzas (1965), indicate that often there is an abundance of Foraminifera under such conditions.

The Foraminifera are obviously not distributed at random but a more sophisticated classification than 'have' and 'have not' subareas is not warranted from the data of this study. If a more complex (several categories) multispecies distributional pattern can be defined geographically, it exists on a scale for which the sampling of this study is inadequate.

Although R. H. Parker et al (1964) recorded a large amount of data on several environmental variables in the Hadley Harbor Complex, the distribution of the Foraminifera is too heterogeneous and the foraminiferal samples too few to permit statistical analysis. The Hadley Harbor Complex does, however, serve as an illustration of an area where the distribution of the Foraminifera can be characterized as exhibiting spatial heterogeneity.

CATALOG OF SPECIES WITH SELECTED SYNONOMIES

Only a species list and synonomy is presented here. All the species recorded in the Hadley Harbor Complex have been adequately described and illustrated in studies made of adjacent areas. These studies are listed in the synonomy and the reader interested in taxonomic studies is referred to them. The overall fauna is typical of what one would expect to find in the shallow waters of New England.

AMMONIA BECCARII (Linné)

Nautilus beccarii Linné, 1758, Syst. Nat., ed. 10, p. 710.
Rotalia beccarii (Linné).—Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, pp. 457-458, pl. 5, figs. 5a,b; 7a; 8a,b.
Ammonia beccarii (Linné).—Cifelli, 1962, Contr. Cushman Found. Foram. Res., vol. 13, pp. 119-126, pls. 21, 22.

AMMOSCALARIA FLUVIALIS Parker

Ammoscalaria fluvialis Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 444, pl. 1, figs. 24, 25.

BOLIVINA PSEUDOPLICATA Heron-Allen and Earland

Bolivina pseudoplicata Heron-Allen and Earland, 1930, Journ. Roy. Micr. Soc., vol. 50, p. 81, pl. 3, figs. 36-40.—Parker, 1952, Bull. Mus. Comp. Zool., vol.

106, no. 10, pp. 444-445, pl. 4, fig. 11.—Todd and Low, 1961, Contr. Cushman Found. Foram. Res., vol. 12, p. 16, pl. 1, fig. 19.

BOLIVINA VARIABILIS (Williamson)

Textularia variabilis Williamson, 1858, Rec. Foram. Great Britain, p. 76, pl. 6, figs. 162, 163.

Bolivina variabilis (Williamson).—Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 445, pl. 4, fig. 12.—Buzas, 1965, Smithsonian Misc. Coll., vol. 149, no. 1, p. 61, pl. 3, fig. 6.

BUCCELLA FRIGIDA (Cushman)

Pulvinulina frigida Cushman, 1922, Contr. Can. Biol., no. 9 (1921), p. 12.

Eponides frigidus (Cushman).—Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 449, pl. 5, figs. 2a,b.

Buccella frigida (Cushman).—Todd and Low, 1961, Contr. Cushman Found. Foram. Res., vol. 12, p. 18, pl. 1, figs. 24, 25.—Buzas, 1965, Smithsonian Misc. Coll., vol. 149, no. 1, p. 62, pl. 4, figs. 2a,b, 3a,b.

CIBICIDES LOBATULUS (Walker and Jacob)

Nautilus lobatulus Walker and Jacob, 1798, Adams Essays, Kanmachers' ed., p. 642, pl. 14, fig. 36.

Cibicides lobatulus (Walker and Jacob).—Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 446, pl. 5, figs. 11a,b.—Todd and Low, 1961, Contr. Cushman Found. Foram. Res., vol. 12, p. 21, pl. 2, fig. 20.

EGGERELLA ADVENA (Cushman)

Verneuilina advena Cushman, 1921, Contr. Can. Biol., no. 9, p. 141.

Eggerella advena (Cushman).—Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 447, pl. 2, fig. 3.—Todd and Low, 1961, Contr. Cushman Found. Foram. Res., vol. 12, p. 14, pl. 1, fig. 4.—Buzas, 1965, Smithsonian Misc. Coll., vol. 149, no. 1, pp. 55-56, pl. 1, figs. 4, 5.

ELPHIDIUM CLAVATUM Cushman

Elphidium incertum (Williamson) var. *clavatum* Cushman, 1930, U. S. Nat. Mus. Bull. 104, pt. 7, p. 20, pl. 7, figs. 10a,b.

Elphidium incertum (Williamson) and variants.—Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 448, pl. 3, figs. 14, 16, 17, pl. 4, figs. 1, 2.

Elphidium clavatum Cushman.—Loeblich and Tappan, 1953, Smithsonian Misc. Coll., vol. 121, no. 7, pp. 98-99, pl. 19, figs. 8-10.—Todd and Low, 1961, Contr. Cushman Found. Foram. Res., vol. 12, pp. 18-19, pl. 2, fig. 1.—Buzas, 1965, Smithsonian Misc. Coll., vol. 149, no. 1, pp. 58-59, pl. 2, figs. 6, 7, pl. 3, figs. 1, 2; Journ. Paleont., 1966, vol. 40, p. 591-592, pl. 71, figs. 1-8.

ELPHIDIUM INCERTUM (Williamson)

Polystomella umbilicatula var. *incerta* Williamson, 1858, On the Recent Foraminifera of Great Britain, The Ray Soc., London, p. 44, pl. 3, fig. 82a.

Elphidium varium Buzas, 1965, Smithsonian Misc. Coll., vol. 145, no. 8, p. 21, pl. 2, fig. 7, pl. 3, figs. 1, 2a,b.

Elphidium incertum (Williamson).—Buzas, 1966, Journ. Paleontol., vol. 40, p. 592- 593, pl. 72, figs. 1-6.

ELPHIDIUM MARGARITACEUM Cushman

Elphidium advenum (Cushman) var. *margaritaceum* Cushman, 1930, U. S. Nat. Mus. Bull. 104, pt. 7, p. 25, pl. 10, fig. 3.—Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 447, pl. 3, fig. 10.

Elphidium margaritaceum Cushman.—Todd and Low, 1961, Contr. Cushman Found. Foram. Res., vol. 12, p. 19-20, pl. 2, fig. 3.

ELPHIDIUM SUBARCTICUM Cushman

Elphidium subarcticum Cushman, 1944, Cushman Lab. Foram. Res. spec. publ. 12, p. 27, pl. 3, figs. 34, 35.—Buzas, 1966, Journ. Paleontol., vol. 40, p. 593, pl. 72, figs. 7-10.

ELPHIDIUM TISBURYENSE (Butcher)

Nonion tisburyensis Butcher, 1948, Contr. Cushman Lab. Foram. Res., vol. 24, p. 22, text-figs. 1-3.—Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 453, pl. 3, figs. 7, 8.

Protelphidium tisburyense (Butcher).—Todd and Low, 1961, Contr. Cushman Found. Foram. Res., vol. 12, p. 21, pl. 2, fig. 12.

Elphidium tisburyense (Butcher).—Buzas, 1965, Smithsonian Coll., vol. 149, no. 1, p. 60, pl. 3, fig. 4.

FISSURINA LAEVIGATA Reuss

Fissurina laevigata Reuss, 1849, Denkschr. Akad. Wiss. Wien, vol. 1, pp. 366, pl. 46, fig. 1.—Buzas, 1965, Smithsonian Misc. Coll., vol. 149, no. 1, p. 58, pl. 2, fig. 3.

MILIAMMINA FUSCA (Brady)

Quinqueloculina fusca Brady, 1870, Ann. Mag. Nat. Hist., ser. 4, vol. 6, p. 47, pl. 11, figs. 2a-c, 3.

Miliammina fusca (Brady).—Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 452, pl. 2, figs. 6a,b.—Todd and Low, 1961, Contr. Cushman Found. Foram. Res., vol. 12, p. 14, pl. 1, fig. 6.

PATEORIS HAUERINOIDES (Rhumbler)

Quinqueloculina subrotunda (Montagu) forma *hauerinoides* Rhumbler, 1936, Kiel Merrsef., Kiel, Deutschland, vol. 1, no. 1, pp. 206, 207, 226, text-figs. 167, 208-212.

Pateoris hauerinoides (Rhumbler).—Loeblich and Tappan, 1953, Smithsonian Misc. Coll., vol. 121, no. 7, p. 42, pl. 6, figs. 8-12, text-figs. 1a,b.—Buzas, 1965, Smithsonian Misc. Coll., vol. 145, no. 8, p. 17, pl. 1, fig. 5.

PSEUDOPOLYMORPHINA NOVANGLIAE (Cushman)

Polymorphina lactea (Walker and Jacob) var. *novangliae* Cushman, 1923, U. S. Nat. Mus. Bull. 104, pt. 4, p. 146, pl. 39, figs. 6-8.
Pseudopolymorphina novangliae (Cushman).—Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 455, pl. 3, figs. 11, 12.—Todd and Low, 1961, Contr. Cushman Found. Foram. Res., vol. 12, p. 16, pl. 1, fig. 26.—Buzas, 1965, Smithsonian Misc. Coll., vol. 149, no. 1, p. 58, pl. 2, fig. 4.

QUINQUELOCULINA SEMINULA (Linné)

Serpula seminulum Linné, 1758, Syst. Nat., ed. 10, p. 786.
Quinqueloculina seminula (Linné).—Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 456, pl. 2, figs. 8a,b.—Todd and Low, 1961, Contr. Cushman Found. Foram. Res., vol. 12, p. 15, pl. 1, fig. 14.—Buzas, 1965, Smithsonian Misc. Coll., vol. 149, no. 1, p. 56, pl. 1, fig. 6.

ROSALINA COLUMBIENSIS (Cushman)

Discorbis columbiensis Cushman, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 2, p. 43, pl. 6, figs. 13a-c.—Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 446, pl. 4, figs. 17a,b, 18a,b, 19a,b, 20a,b.
Rosalina columbiensis (Cushman).—Todd and Low, 1961, Contr. Cushman Found. Foram. Res., vol. 12, p. 17, pl. 1, figs. 20, 21.

TROCHAMMINA INFLATA (Montagu)

Nautilus inflatus Montagu, 1808, Testacea Britannica, Suppl., p. 81, pl. 18, fig. 3.
Trochammina inflata (Montagu).—Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 459, pl. 3, figs. 1a,b.—Todd and Low, 1961, Contr. Cushman Found. Foram. Res., vol. 12, p. 15-16, pl. 1, figs. 22, 23.—Buzas, 1965, Smithsonian Misc. Coll., vol. 149, no. 1, p. 57, pl. 1, figs. 9a,b.

TROCHAMMINA SQUAMATA Parker and Jones

Trochammina squamata Parker and Jones, 1865, Philos. Trans. Roy. Soc. London, vol. 155, p. 407, pl. 15, figs. 30, 31a,b,c.—Buzas, 1965, Smithsonian Misc. Coll., vol. 149, no. 1, p. 57-58, pl. 2, figs. 2a,b.
Trochammina squamata Parker and Jones and related species.—Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 460, pl. 3, figs. 4a,b.

TROCHAMMINA MACRESCENS Brady

Trochammina inflata (Montagu) var. *macrescens* Brady, 1870, Ann. Mag. Nat. Hist., ser. 4, vol. 6, p. 51, pl. 11, figs. 5a-c.
Trochammina macrescens Brady.—Parker, 1952, Bull. Mus. Comp. Zool., vol. 106, no. 10, p. 460, pl. 3, figs. 3a,b.—Todd and Low, 1961, Contr. Cushman Found. Foram. Res., vol. 12, p. 16, pl. 1, fig. 16.

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1952. Techniques for the recognition of living Foraminifera. Contr. Cushman Found. Foram. Res., vol. 3, pp. 56-60.

TABLES

TABLE 1.—*Number of individuals for each species in the living and total population* (G = grab sample; C = core sample; ′ = replicate)

	STATION							
SPECIES	95G		96G		97G		98G	
	L	T	L	T	L	T	L	T
Ammonia beccarii		30			2	2		
Ammoscalaria fluvialis		3						4
Bolivina pseudoplicata								
Bolivina variabilis								
Buccella frigida		3			11	12		
Cibicides lobatulus				2				
Eggerella advena				2				
Elphidium clavatum		53		24	7	12		
Elphidium incertum		5		10		1		
Elphidium margaritaceum	2	2		1				
Elphidium subarcticum		3	1	2		1		
Elphidium tisburyense			3	9				
Elphidium sp.	6	6						
Fissurina laevigata								
Miliammina fusca								1
Pateoris hauerinoides		2						
Pseudopolymorphina novangliae				4				
Quinqueloculina seminulum		1	16	34				
Rosalina columbiensis								
Trochammina inflata								1
Trochammina macrescens								
Trochammina squamata		1	1	4		1		1
TOTAL	8	109	21	90	20	31	0	7

STATION											
99C		100C		102G		105G		106′C		107G	
L	T	L	T	L	T	L	T	L	T	L	T
							8		1	1	1
1	1		7								
						5	19			13	20
				3	7				1		
						7	34			6	30
						15	27			4	7
								1	1		
							2				1
							2				
										14	15
									1		1
			4		1				1		
1	1	0	11	3	8	27	92	1	5	38	76

Table 1.—*Number of individuals for each species in the living and total populations.*—Continued

SPECIES	STATION 108′G L	108′G T	110G L	110G T	111′C L	111′C T	112G L	112G T
Ammonia beccarii			2	2			12	105
Ammoscalaria fluvialis								
Bolivina pseudoplicata								
Bolivina variabilis								
Buccella frigida					4	6	14	160
Cibicides lobatulus								
Eggerella advena				2		6	3	4
Elphidium clavatum					8	69	131	586
Elphidium incertum			2	2		7	30	117
Elphidium margaritaceum			2	2	2	4	7	24
Elphidium subarcticum						8	7	22
Elphidium tisburyense								17
Elphidium sp.							4	7
Fissurina laevigata								
Miliammina fusca								
Pateoris hauerinoides								
Pseudopolymorphina novangliae								
Quinqueloculina seminulum								
Rosalina columbiensis								
Trochammina inflata		6						1
Trochammina macrescens						2		
Trochammina squamata		1				9		7
Unknown							2	2
Total	0	7	6	8	14	111	210	1052

STATION											
114G		115G		116G		117G		119G		259G	
L	T	L	T	L	T	L	T	L	T	L	T
			1							40	66
					15		3				
										1	1
										1	1
			4							3	4
										2	2
	2				1		2			25	28
			1			1	1			7	11
			1							15	16
			1							16	37
										19	30
2	2										
											5
										6	8
										4	6
											2
			4		1				5		
								1	1		
	4		3		1		2				1
										4	5
2	8	0	15	0	18	1	8	1	6	143	223

TABLE 1.—*Number of individuals for each species in the living and total populations.*—Continued

SPECIES	STATION 259′G L	259′G T	260G L	260G T	261G L	261G T	262G L	262G T
Ammonia beccarii	22	72	105	157		1	2	8
Ammoscalaria fluvialis		1						
Bolivina pseudoplicata								
Bolivina variabilis								
Buccella frigida		2	38	53			4	6
Cibicides lobatulus								
Eggerella advena	4	36	3	7				
Elphidium clavatum	5	9	89	148		5	78	102
Elphidium incertum	4	7	31	45		3	1	1
Elphidium margaritaceum		22	19	35				
Elphidium subarcticum	12	35	107	152			5	7
Elphidium tisburyense								
Elphidium sp.								
Fissurina laevigata								
Miliammina fusca		1		1				
Pateoris hauerinoides								
Pseudopolymorphina novangliae								
Quinqueloculina seminulum				2				
Rosalina columbiensis		2						
Trochammina inflata		1		1				
Trochammina macrescens								
Trochammina squamata		2						
Unknown								
TOTAL	47	188	392	601	0	9	90	124

STATION											
262′G		263G		264G		264′G		265G		265′G	
L	T	L	T	L	T	L	T	L	T	L	T
	1			9	18	19	22	1	1		
		62	66	32	57	22	29				
								1	1		
		205	217	35	78	35	43				
		1	1	3	14	3	3	5	5		
		5	6	1	4						
		7	10	1	4	23	24			3	3
		2	4				2				
						1	1				
								1	1		
	1				1		1				
							6				
0	2	282	304	81	176	103	131	8	8	3	3

Table 1.—*Number of individuals for each species in the living and total populations.*—Continued

SPECIES	STATION 266G L	266G T	266′G L	266′G T	267G L	267G T	267′G L	267′G T
Ammonia beccarii								
Ammoscalaria fluvialis								
Bolivina pseudoplicata								
Bolivina variabilis								
Buccella frigida		2						
Cibicides lobatulus								
Eggerella advena								
Elphidium clavatum	1	6						
Elphidium incertum		6						
Elphidium margaritaceum								
Elphidium subarcticum								
Elphidium tisburyense								
Elphidium sp.								
Fissurina laevigata								
Miliammina fusca								
Pateoris hauerinoides								
Pseudopolymorphina novangliae								
Quinqueloculina seminulum								
Rosalina columbiensis								
Trochammina inflata								
Trochammina macrescens								
Trochammina squamata		2						
Total	1	16	0	0	0	0	0	0

STATION													
268G		269G		270G		270′G		271G		271′G		272G	
L	T	L	T	L	T	L	T	L	T	L	T	L	T
				6	40		23	10	13	4	8		1
					14		6	19	35	1	17	10	18
				1	1		1		2				
				2	29		25	40	81		17	60	237
				3	19		8	7	19	5	8	6	11
					2			1	3		2		5
				1	4			5	5		2	59	77
							1		2		1		
				8	9		2						
							2		1				
					7		3				2		
0	0	0	0	21	125	0	71	82	161	10	57	135	349

TABLE 2.—*Chi-square analyses of sample pairs. The actual number of individuals observed is columned under (O). The expected frequency (e) of a species in a sample is calculated by multiplying the sum of the species row by the sum of the sample column and dividing by the total sum of both samples. Chi-square is calculated by the formula* $\sum_{\text{cells}} \frac{(o-e)^2}{e}$.

SAMPLE PAIR 259–259′

Live Population

	259 o	259′ o	Total	259 e	259′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
Ammonia beccarii	40	22	62	45.37	16.65	.64	1.72
Eggerella advena	25	4	29	21.21	7.78	.68	1.84
Elphidium clavatum	7	5	12	8.78	3.22	.36	.98
Elphidium incertum	15	4	19	13.90	5.10	.09	.24
Elphidium margaritaceum	16	0	16	11.70	4.30	1.58	4.30
Elphidium subarcticum	19	12	31	22.67	8.32	.59	1.63
Pseudopolymorphina novangliae	6	0	6	4.39	1.61	.59	1.61
Total	128	47	175	128.02	46.98	4.53	12.32

$\chi^2_6 = 16.85$*

SAMPLE PAIR 259–259′

Total Population

	259 o	259′ o	Total	259 e	259′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
Ammonia beccarii	66	72	138	73.72	64.28	.81	.93
Buccella frigida	4	2	6	3.20	2.79	.20	.22
Eggerella advena	28	36	64	34.19	29.81	1.12	1.28
Elphidium clavatum	11	9	20	10.68	9.32	.01	.01
Elphidium incertum	16	7	23	12.29	10.71	1.12	1.28
Elphidium margaritaceum	37	22	59	31.52	27.48	.95	1.09
Elphidium subarcticum	30	35	65	34.72	30.28	.64	.74
Miliammina fusca	5	1	6	3.20	2.79	1.01	1.15
Pseudopolymorphina novangliae	8	0	8	4.27	3.73	3.26	3.73
Quinqueloculina seminula	6	0	6	3.20	2.79	2.45	2.79
Total	211	184	395	210.38	183.98	11.57	13.22

$\chi^2_9 = 24.79$*

* Significant at 95% level.

SAMPLE PAIR 262–262′

Live Population

	262 *o*	262′ *o*	Total	262 *e*	262′ *e*
Elphidium clavatum	78	0	78	78	0
Elphidium subarcticum	5	0	5	5	0
Total	83	0	83	83	0

SAMPLE PAIR 262–262′

Total Population

	262 *o*	262′ *o*	Total	262 *e*	262′ *e*
Ammonia beccarii	8	1	9	8.93	.07
Buccella frigida	6	0	6	5.95	.05
Elphidium clavatum	102	0	102	101.18	.82
Elphidium subarcticum	7	0	7	6.94	.06
Total	123	1	124	123.00	1.00

SAMPLE PAIR 264–264′

Live Population

	264 *o*	264′ *o*	Total	264 *e*	264′ *e*	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
Ammonia beccarii	9	19	28	12.31	15.69	.89	.70
Buccella frigida	32	22	54	23.74	30.26	2.87	2.25
Elphidium clavatum	35	35	70	30.77	29.23	.58	.46
Elphidium incertum	3	3	6	2.64	3.36	.05	.04
Elphidium subarcticum	1	23	24	10.55	13.45	8.64	6.78
Total	80	102	182	80.01	102.00	13.03	10.23

$$\chi^2_4 = 23.26^*$$

SAMPLE PAIR 264–264′

Total Population

	264 *o*	264′ *o*	Total	264 *e*	264′ *e*	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
Ammonia beccarii	18	22	40	23.42	16.58	1.25	1.77
Buccella frigida	57	29	86	50.36	35.64	.80	12.80
Elphidium clavatum	78	43	121	70.86	50.14	.72	15.48
Elphidium incertum	14	3	17	9.96	7.04	1.64	6.88
Elphidium subarcticum	4	24	28	16.40	11.60	4.98	4.98
Total	171	121	292	171.00	121.00	9.39	41.91

$$\chi^2_4 = 51.30^*$$

* Significant at 95% level.

SAMPLE PAIR 266–266′

Total Population

	266 o	266′ o	Total	266 e	266′ e
Elphidium clavatum	6	0	6	0	0
Elphidium incertum	6	0	6	0	0
Total	12	0	12	0	0

SAMPLE PAIR 270–270′

Live Population

	270 o	270′ o	Total	270 e	270′ e
Ammonia beccarii	6	0	6	0	0
Pseudopolymorphina novangliae	8	0	8	0	0
Total	14	0	14	0	0

SAMPLE PAIR 270–270′

Total Population

	270 o	270′ o	Total	270 e	270′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
Ammonia beccarii	40	23	63	40.18	22.82	0	0
Buccella frigida	14	6	20	12.76	7.24	.12	.21
Elphidium clavatum	29	25	54	34.44	19.56	.86	1.51
Elphidium incertum	19	8	27	17.22	9.78	.18	.32
Pseudopolymorphina novangliae	9	2	11	7.02	3.98	.56	.98
Trochammina inflata	7	3	10	6.38	3.62	.06	.11
Total	118	67	185	118.00	67.00	1.78	3.13

$$\chi^2_5 = 4.91$$

SAMPLE PAIR 271–271′

Live Population

	271 o	271′ o	Total	271 e	271′ e
Ammonia beccarii	10	4	14	12.46	1.54
Buccella frigida	19	1	20	17.80	2.20
Elphidium clavatum	40	0	40	35.60	4.40
Elphidium incertum	7	5	12	10.68	1.32
Elphidium subarcticum	5	0	5	4.45	.56
Total	81	10	91	80.99	10.02

SAMPLE PAIR 271–271′

Total Population

	271 o	271′ o	Total	271 e	271′ e	$\frac{(o-e)^2}{e}$	$\frac{(o-e)^2}{e}$
Ammonia beccarii	13	8	21	15.70	5.30	.46	1.38
Buccella frigida	35	17	52	38.87	13.13	.38	1.14
Elphidium clavatum	81	17	98	73.25	24.75	.82	2.43
Elphidium incertum	19	8	27	20.18	6.82	.07	.20
Total	148	50	91	148.00	50.00	1.73	5.15

$$\chi^2_3 = 6.88$$